A method and an arrangement for controlling position and/or force of an elongated rolling device

The invention relates to a method as defined in the preamble of claim 1 and to an arrangement as defined in the preamble of claim 4 for controlling the position and/or force of an elongated rolling device in the roll nip between two elongated rolling devices in paper and board machines.

The nip pressure in a roll nip between two rolls and the opening and closing of the roll nip are adjusted with hydraulic means connected to said rolls, such as hydraulic cylinders. For nip pressure control, suitable measuring means are first used for measuring the force/pressure generated by the roll in the roll nip, the control logic of the control system converts an analogue measurement signal into a digital signal and transmits a control signal in digital form to the control valve in charge of changing the nip pressure. The digital control signal is converted into analogue form by the control valve, and then the control valve controls the fluid flow entering and leaving the hydraulic means. Such a manner of controlling nip pressure has noticeable shortcomings, of which the major ones relate to disappearing data content as an analogue measurement signal is converted into digital form and a digital control signal is subsequently converted into a control signal.

There are frequently also problems caused by the fact that the same relatively large-sized control valve, such as a proportional valve, is used for controlling both the force exerted by the roll on the backing roll in the roll nip between the rolls and also the roll position relative to the backing roll. This problem is particularly tangible in reelers, because, as the fibre web is reeled around the reel core, the reel core needs to be continuously shifted away from the reeling cylinder. However, meanwhile it is necessary to maintain the nip pressure between the reel core and the reel cylinder on a determined level. The shift of the location of the reel core requires relatively large movements of the piston of the hydraulic means and also changes of the fluid pressure prevailing in the compression cylinder, whereas changes of the nip pressure can be achieved with considerably smaller piston movements and changes of the fluid pressure in the compression cylinder, entraining a tendency to cause control fluctuation and vibrations in the roll/rolls. In practice, due to the great mass of the control valve and the consequently slow changes of the flow volume in the

hydraulic means, it is often difficult or even impossible to actively attenuate roll vibrations caused by control fluctuation by means of control engineering means.

Controlling hydraulic means by current control valves such as servo valves and proportional valves is awkward and inaccurate, because the required valves are bulky and slow, and thus have poor control resolution. In addition, the control valves themselves might cause control fluctuation and vibrations in the rolling devices by their own operation.

The purpose of the invention is to eliminate the prior art inconveniences. Thus, the first purpose of the invention is to achieve a system for controlling the location and the force of the roll, allowing the same hydraulic means to accurately control both the location of the roll relative to the backing roll in the roll nip and also the nip pressure (= force) generated by the roll in the roll nip, substantially without control fluctuation. A second purpose of the invention is to achieve an active manner of control enabling efficient attenuation of roll vibrations.

The goals defined above are achieved by means of the method and arrangement of the invention.

The invention relates to a method as defined in claim 1 and to an arrangement as defined in claim 4 for adjusting the location and/or force of an elongated rolling device in the roll nip between two elongated rolling devices.

The invention is based on the feature of controlling the nip pressure of a roll nip and the opening and closing of the roll nip with a hydraulic means, the volume flow arriving to the hydraulic means being at least partly controlled by a digital valve pack. The control signals utilised by the digital valve pack and transmitted by the control system are both in digital form, achieving the notable benefit over analogue valves that control information does not require conversion from digital to analogue form, so that no information will be lost while a digital control signal from the control system is converted into an analogue control signal.

Use of the digital valve pack as switch means, allows very accurate control of the volume flow reaching the hydraulic means; thus, for instance, replacement of a large proportional valve with a digital valve pack containing 12 on/off digital valves provides a control resolution of 4096 different volume flows. What is more, on/off

digital valves have markedly fast operation, so that the same digital valve pack allows control of the same hydraulic means both during shifts of the roll location, requiring large volume flow changes, while closing and opening of the roll nip, and also during changes of the nip pressure requiring relatively small volume flow changes.

In this patent application, at least one of the rolling devices in the roll nip between two elongated rolling devices is a roll used in paper and board machines, such as a calendaring roll or a reeler roll. The other of the rolling devices can then be a roll or an elongated roll-like array, such as a doctor blade, or the blade of a coating applicator used in fibre web coating, without being confined to these, however.

A digital valve stands for a valve having $N^{(\text{number of valves})}$ states; and between two successive states, the valve is driven directly from the first state to the second state. The valve preferably has two states; it is either completely open or completely closed. When the valve is open, it is permeated by the entire volume flow rate of fluid allowed by this particular valve, and when the valve is closed, it is not permeated by fluid at all. In this application, a digital valve having two states is also referred to as an on/off valve and an on/off digital valve. A digital valve may have more than two states, and then the valve is driven stepwise from one state to another. The digital valve preferably has three positions; the valve transmits fluid flow into a first and a second direction, or then the valve does not transmit fluid. A digital valve pack including such digital valves having three states then has N^3 states, in which N is the number of valves in the digital valve pack.

In the method of the invention for adjusting the location and/or force of an elongated rolling device in the roll nip between two elongated rolling devices in paper and board machines, the location of the rolling device relative to the other rolling device and/or the force exerted by the rolling device on another rolling device or any variable acting on these are measured, and the measured variable value is compared with the set value of said variable to obtain the difference value of the variable. The difference value is used for adjusting the location of the rolling device relative to the other rolling device and/or the force exerted by the rolling device on the other rolling device. The fluid pressure of the hydraulic means and/or the flow velocity of the liquid to the hydraulic means is altered in order to change the difference value by opening and/or closing at least one digital valve in a digital valve pack functionally connected to the hydraulic means.

The arrangement, in turn, includes a measurement means for measuring the location of the rolling device and/or the force it exerts on the other rolling device, or any variable acting on these, and for transmitting a measurement signal to the control system. The arrangement further comprises a hydraulic means, by means of which the location of the rolling device is shifted relative to the other rolling device and/or the force exerted by the rolling device on the other rolling device in the roll nip is changed, a switch means for adjusting the volume flow of the hydraulic means, a control system for receiving a measurement signal and for comparing the information in the measurement signal with the set value of the variable in order to provide a control signal and to transmit it to the switch means. The switch means has receive means for receiving and processing a control signal and also at least one digital valve pack, which comprises digital valves, preferably on/off digital valves, which can be switched on and off on the basis of a control signal, so that the fluid pressure of the hydraulic means and/or the flow velocity of the liquid to the hydraulic means change.

In a preferred embodiment of the invention, the fluid pressure of the hydraulic means and/or the flow velocity of the fluid to the hydraulic means is changed on the basis of a digital control signal from the control system by means of the digital valve pack, without converting the control signal into analogue form in the meantime. Then the measurement means generates an analogue measurement signal, on the basis of which the control system transmits a digital control signal to the digital valve pack that changes the flow rate and/or the fluid pressure of the hydraulic means.

In the invention, the control signals received and used by the digital valve pack are digital and the control signals from the control system to the digital valve pack are already in digital from, so that the control signal does not require conversion from digital form into analogue form, as would be the case if the liquid flow of the hydraulic means were adjusted with an analogue control valve. This achieves the marked advantage over analogue valves, that control information cannot be lost between the control system and the switch means (digital valve pack).

In another preferred embodiment of the invention, the location of the rolling device in the roll nip and the force it exerts on another rolling device in the roll nip are adjusted by the same hydraulic means and the amount and velocity of said volume

flow of the hydraulic means are changed by means of one or more digital valve packs.

In a further preferred embodiment of the invention, the measurement means performs measuring of the amplitude and frequency of the roll vibration and the control system determines the counter vibration for this rolling device vibration (difference value), on the basis of which selected digital valves in the digital valve pack are opened and closed. The counter vibration should be such that the amplitude of the measured roll vibration decreases towards its set value.

In the last mentioned embodiment of the invention, a digital valve pack allows for active vibration attenuation of the roll in a roll nip, unlike analogue control valves. Using digital valves, the volume flow of the hydraulic means can be rapidly and accurately increased and decreased with good volume flow resolution, so that even minor vibrations in the roll nip can be attenuated. This offers the further potential feature of using the digital valve pack alongside a conventional analogue control valve, such as a proportional valve; the control valve serves to open/close a roll nip between the rolling device and possibly also to control the nip pressure between two rolling device in the roll nip. The vibration of the rolling device in the roll nip is attenuated with active control operations by using digital valves alongside the analogue valves mentioned above for controlling the volume flow to and from the hydraulic means.

The invention is described below in further detail with reference to the accompanying figures.

Figure 1 shows a roll nip between two rolls viewed from the end of the roll pair, and also the arrangement used for controlling the nip pressure in the roll nip.

Figure 2 also shows a roll nip between two rolls viewed from the end of the roll pair, and the arrangement used for controlling the opening and the closing of the roll nip.

Figures 3A and 3E show a roll nip between two rolls viewed from the end of the roll pair. The figures illustrate the apparatus used for attenuating vibrations of the roll nip. Figures 3B to 3D show the attenuation of vibrations generated in the apparatuses by using the arrangement of the invention.

Figure 4 is a schematic view of the roll nip between the reel cylinder of a reeler and the reel core, viewed from the end of the roll pair formed by the reel cylinder and reel core, and also the arrangement used for controlling the location of the reel core of the reeler and the nip force.

Figures 5A and 5B shows a roll nip viewed from the end of the pair of rolls in an apparatus used for fibre web coating, and the arrangement used for opening and closing the roll nip and for controlling the nip pressure.

Figure 6A is a schematic lateral view of a multi-zone roll and of the control arrangement used for pressurising its different zones. Figure 6B shows an arrangement for controlling a multinip calender using the multi-zone roll of figure 6A as the lowermost and the uppermost roll.

Figure 7A is a block view of the arrangement of the invention and figure 7B is a block view of the method of the invention.

The following examination starts with the main features of the designs and functions of the illustrated apparatuses and also the object to be illustrated by each figure.

Figure 1 shows a simple roll nip N between the rolls of a pair 2 of two rolls, the nip pressure being controlled with the control arrangement 1 of the invention. The control arrangement comprises a hydraulic actuator 5, a measurement means 4, a digital valve pack 7 and a control system 3.

Figure 2 also shows a simple roll nip N between the rolls of a roll pair 2, the roll nip being opened and closed with the control arrangement 1 of the invention. The control arrangement includes a hydraulic actuator 5, the pressure of the hydraulic fluid prevailing on different sides of the cylinder relative to the piston head being controlled with two separate digital valve packs 7; 7a, 7b. The operation of the digital valve packs is controlled by the control system 3.

Figure 3A shows a simple roll nip N between the rolls of a roll pair 2, whose vibrations are attenuated with the control arrangement 1, which includes a control system 3, two digital valve packs 7; 7a, 7b, and a hydraulic actuator 5, the pressure

of the hydraulic fluid prevailing on different sides of the cylinder relative to the piston head being controlled with said digital valve packs.

Figure 3B shows a vibration measured in the roll nip of the apparatus of figure 3A, the vibration having a given amplitude A1 and frequency f.

Figure 3C shows a counter-vibration having a phase opposite to that of figure 3B and generated by opening and closing the valves in the digital valve pack, and having a frequency f and an amplitude A2.

Figure 3D shows an attenuated vibration in the roll nip, the vibration having a frequency f and an amplitude A3. The attenuated vibration is the sum vibration of the vibrations of figures 3B and 3C.

Figure 3E illustrates a simple roll nip N between the rolls of a roll pair 2, whose vibrations are attenuated with the control arrangement, which includes a control system (not shown in the figure), a digital valve pack 7; 72 and a hydraulic actuator 5. The arrangement also comprises an analogue valve 7; 71, which serves for controlling the nip pressure prevailing in the roll nip and also the opening and closing of the roll nip. This is hence a hybrid system, whose switch means 7 includes both an analogue and a digital switch means.

Figure 4 illustrates the reel cylinder 2 and the reel core 21 of the reeler 9. The fibre web W is reeled around the reel core 21, and in this conjunction, the reel core needs to be displaced as the thickness s of the fibre web increases on the reel core 21. However, meanwhile, a given nip pressure needs to be maintained in the roll nip N in order to ensure regular reeling of the fibre web around the reel core. Both the location of the reel core relative to the reel cylinder and the nip pressure in the roll nip between the reel core and the reel cylinder are adjusted by the control arrangement 1, which includes a control system 3, a digital valve pack 7, measurement means 4 and a hydraulic means 5. The form of control signals 31 determine whether to change the location of the reel core with the digital valve pack relative to the reel cylinder, or the force F exerted by the reel core on the reel cylinder, i.e. the nip pressure prevailing in the roll nip. The same control arrangement 1 also enables attenuation of vibrations in the roll nip.

Figure 5A shows an apparatus 10 for coating a fibre web which is conventional *per se*, comprising a roll pair 2 of two rolls, spaced by the roll nip N. The fibre web W runs obliquely from the top downward and the coating agent is transferred from the rolls 2 onto the fibre web in the roll nip N. Inversely, the coating agent is transferred onto the surface of the rolls 2; 21, 22 at coating stations (application stations) 6.

Figure 5B illustrates an arrangement 1 for controlling the fibre web coating apparatus of figure 5A, comprising a control system 3, sensors 4, which measure the nip pressure (or the force exerted by the roll in the roll nip) and also the position of the roll in the roll nip. The control arrangement of the figure illustrates not only the application of the control system of the invention to a fibre web coating apparatus, but also the processing of measurement signals 41 from the sensors 4 by the control system 3 into control signals 31, which control the switch means 7, which is a digital valve pack.

Figure 6A illustrates a control arrangement 1 of the invention, in which pressurising means 5; 51 within the mantle of a multi-zone roll 23 and pressurising means 5; 52 outside the roll at the roll ends are controlled in accordance with the invention by digital valve packs 7; 71 and 7; 72 and also the control system 3.

Figure 6B shows a multinip calender 20, which comprises three idle rolls 24 and a lower roll 23; 23b and an upper roll 23; 23a, of which the latter have design and operation of the pressurising means inside and outside the rolls identical to those of figure 6A. The figure illustrates the implementation of the control arrangement 1 of the invention in multinip calendars 20. Hydraulic actuators 5 connected both to the idle rolls and to the lower and upper rolls are controlled by means of digital valve packs 7, which, in turn receive their control signals 31 from the control system 3.

Figure 7A shows the control arrangement 1 of the invention on a block diagram level. The arrangement serves for measuring and controlling the nip pressure of the roll nip N and/or the location of the rolls or any variables acting on these.

Figure 7B, in turn, shows a method of the invention on a block diagram level. The method measures and controls by means of the difference variable the nip pressure of the roll nip N and/or the location of the rolls, or any variables acting on these.

The invention is described in greater detail below.

The control of the nip pressure in the roll nip N between a roll pair 2 of two rolls 21, 22 is illustrated in figure 1. The roll pair 2 may be located in a calender, for instance, where a fibre web W runs between the rolls, the fibre web being calendered (profiled) on its surface as it passes through the roll nip N. A hydraulic cylinder 5 is connected to the roll 21 over a lever arm 52 (piston). The pressure of the hydraulic fluid of the compression cylinder 51 of the hydraulic actuator 5 (hydraulic cylinder) is controlled by the digital valve pack 7. The pressure of the hydraulic fluid in the compression cylinder generates a specific force, by which the piston 52 acts on the roll 21. The roll 21 then exerts a force F on the stationary backing roll 22, generating a specific nip pressure in the roll nip N between the pair of rolls 2.

The pressure of the hydraulic fluid in the compression cylinder 51 is generated by opening one or more appropriate valves V; V1..V8 of the digital valve pack 7. The digital valve pack comprises eight valves V1..V8 of different sizes, the liquid flow passing through the valves being doubled each time it passes from a smaller digital valve to the next size. The difference between the volume flows of two digital valves with consecutive volume flow rates is thus 100%, in other words, the volume flow of a valve with greater volume flow is always the double of that of a valve with smaller volume flow. The valve sizes are then e.g. valve V1 one l/min., valve V2 two l/min, valve V3 four l/min., etc. When it is desirable to generate e.g. a 10 kN nip pressure in the roll nip, the control system 3 opens valve V1 in the digital valve pack 7, so that hydraulic fluid flows into the compression cylinder 52 at a rate of 1 l/min and the force F exerted by the roll 21 on the backing roll 22 increases. Unless the force F or the nip pressure is desired, the valve V1 is closed and the valve V2 is opened, and the nip pressure and/or the force F are monitored anew. This way of opening and closing the valves V; V1..V8 of the digital valve pack 7 aims at a valve combination that best realises the desired nip pressure. The digital valve pack in figure 1 comprises 8 valves, so that there are 2^8 = number of potential different volume flows, i.e. the digital valve pack has a resolution of 256. When the principally adopted nip pressures are known, all the practically occurring nip pressures can be realised by appropriately staggered volume flow rates of the individual valves in a digital valve pack and by an appropriate number of valves. Having but two states, the valves included in a single digital valve pack have very rapid functions; each valve is either open or closed. With an open valve, the valve transmits the entire volume flow rate of hydraulic fluid allowed by the valve, and

with a closed valve, it is permeated by a zero amount of volume flow. Thus each digital valve operates on the on/off principle known in digital technology. The digital valve pack receives digital control signals from the control system 3. The control system, in turn, receives the pressure/force data it needs from the force sensor 4, which is connected to the shaft 21a of the roll 21.

The arrangement 1 opening and closing the roll nip NO in figure 2 uses two digital valve packs 7; 7a; 7b, which both comprise 8 on/off valves. By means of the valves in the digital valve pack 7a, the pressure of the hydraulic fluid in the compression cylinder 5; 52 is increased in the cylinder portion 51a on the left-hand side of the piston head 52a of the piston 5; 51, and then the roll nip N opens. By contrast, by means of the valves in the digital valve pack 7b, the pressure of the hydraulic fluid is increased in the cylinder portion 51b on the right-hand side of the piston head, so that the roll nip closes. The rate of opening and closing the roll nip N, in turn, depends on the total volume flow rate of the opened valves. Opening different valve combinations achieves different opening rates of the roll nip, which depend on the cross-sectional area of the cylinder and on the fluid amounts flowing through the valves over a given period.

The roll nip is rapidly opened by opening all the valves in the digital valve pack 7; 7b simultaneously, and then no separate rapid opening valve will be necessary. Both the digital valve packs receives their digital control signals 31 from the control system 3. The control system, again, receives the positional data 41 about the roll that it needs from a sensor 4 measuring the roll location or position, the sensor being preferably located in the rear portion of the hydraulic actuator 5 with the hydraulic actuator viewed perpendicularly from the direction of the roll nip. The roll location can be measured either relatively to the backing roll or absolutely. Roll velocity data can also be included in the measurement data, and the velocity data can be measured by means of an acceleration sensor, for instance.

The arrangement of the invention also allows for attenuation of vibrations occurring in the roll nip in several devices used in paper and board machines, such as calenders, reelers, coating devices etc. Figures 3A-3E illustrates how to attenuate vibrations in a roll nip N between the rolls 21, 22 in a roll pair 2 by means of the arrangement 1 of the invention. Vibrations in the roll nip are often due to fluctuating control, hydraulic actuators, eccentric rolls, etc. The roll nip N of a calender is schematically shown in figures 3A and 3E without a fibre web passing through the

roll nip, calender frame structures, etc. The control arrangement 1 in figure 3A includes a sensor 4 for measuring vibrations exerted on the frame of the backing roll 22, a control system 3, two digital valve packs 7; 7a, 7b, and a hydraulic actuator (hydraulic cylinder) 5. Both the digital valve packs comprise 8 on/off valves, so that both have a resolution covering 256 different states (volume flows). The valves in the digital valve packs 7 open and close liquid flows in compression cylinder portions 51; 51a, 51b located on different sides of the piston head 52; 52a, and then the digital valve packs can be used for increasing and decreasing the fluid pressure in the roll nip N. The opening and closing of the valves in the digital valve packs 7 are controlled by the control system 3, which receives vibration data 41 from the sensor 4.

Figure 3B shows a vibration occurring in the roll nip of the apparatus of figure 3A, the vibration having been measured by the vibration sensor 4 of the arrangement 1 of figure 3A. This vibration has an amplitude A1 and a frequency f in the roll nip N. The vibration data 41 are transferred from the sensor 4 to the control system 3. The control system 3 determines a counter-vibration (difference value) for the vibration occurring in the roll nip 3, the phase of this vibration differing from that of the vibration in the roll nip. The counter-vibration is determined on the basis of the amplitude of the maximum permissible vibration (set value), for instance. After this, the control system controls appropriate valves in the digital valve packs 7 in figure 3B so that this particular counter-vibration realises. The counter-vibration is illustrated in figure 3C and it has a frequency f and an amplitude A2. Then the sum vibration in the roll nip is the sum of the vibrations shown in figures 3B and 3C, as shown in figure 3D. The amplitude of the sum vibration is A3 and its frequency is f. The amplitude A3 is smaller than the frequency A, implying attenuation of the vibration. This sum vibration can be remeasured by the sensor 4, and a suitable counter-vibration can be determined for it under the control procedure described above.

Figure 3E, in turn, illustrates a control arrangement 1, in which the switch means 7 comprises a digital valve pack 72 and a conventional proportional valve 71. The nip pressure prevailing in the roll nip N is adjusted in a conventional manner *per se* by means of proportional valve 71, which controls the pressure of the hydraulic fluid prevailing in different portions 51a and 51b of the compression cylinder 5; 51 by the intermediation of fluid transfusion lines s1 and s2. The portion 51a of the compression cylinder is located on the left side of the piston head 52a of the piston

52 moving in the compression cylinder 51, and accordingly, the portion 51b of the compression cylinder is located on the right side of said piston head 52a. With the analogue control valve 71 in position a, the hydraulic fluid flow follows the line s2 to the right side 51b of the cylinder 51, while hydraulic fluid is discharged from the left side 51a of the cylinder along line s1. This increases the nip pressure in the roll nip N. On the other hand, with the control valve 71 in position b, the hydraulic fluid flow decreases the nip pressure in the roll nip N, because the hydraulic fluid flow follows the line s1 to the portion 51a of the compression cylinder 51, to the left side of the piston head, and escapes along line s2 from the portion 51b of the compression cylinder on the right side of the piston head. Should the sensor 4 detect vibrations in the roll nip, they can be attenuated by means of the on/off valves in the digital valve pack 72 by opening and closing digital valves as shown in figures 3B to 3D, by a counter-vibration in a phase opposite to that of the measured vibration. The vibrations to be attenuated may also originate from the operation of an analogue control valve.

The control arrangement of figure 4 is used for positioning the reel core 21 of a reeler 9 relative to the reel cylinder 22 and also for controlling the nip pressure of the roll nip N of a roll pair 2 formed of a reel cylinder and a reel core.

Should a conventional control arrangement with a large-sized control valve be used for shifting the reel core 21 of the reeler relative to the reel cylinder 22 and for maintaining the nip pressure, the control would have a tendency to fluctuate: the change of volume flow of hydraulic fluid required for maintaining the nip pressure between the rolls 21, 22 is relatively small, whereas the change of volume flow of hydraulic fluid required for shifting the location of the reel core in said hydraulic means is relatively great. With the control switching from positioning of the mutual location of the rolls 21, 22 to control of the nip pressure prevailing in the roll nip between said rolls, or vice versa, the mass of a large-sized control valve is one reason of problems in passing from one control state to another, resulting in a tendency of fluctuating control. Fluctuating control, in turn, causes irregular reeling of the fibre web onto the reel core.

In accordance with the invention, the on/off digital valves V included in the digital pack are small-sized and have rapid operation. The control arrangement 1 illustrated in figure 4 comprises a digital valve pack 7, by means of which not only the position of the reel core 21 is adjusted relative to the stationary reel cylinder 22 but

also the nip pressure of the roll nip N between the reel core 21 and the reel cylinder 22. The control arrangement 1 comprises a control system 3, which receives data indicating the location of the reel core 21 from the position sensor 4; 4a and also receives continually or intermittently from the force sensor 4; 4b measurement data 4 indicating the nip pressure in the roll nip N or the force exerted by the reel core 21 on the reel cylinder 22. The position sensor 4; 4a detects the thickness s of the fibre web layer W on the reel core 21, the sensor being usually located in the immediate vicinity of the outer surface of the fibre web W wound around the reel core. Detection of the thickness of the fibre web layer can be performed either by a mechanical position sensor as in the figure, or on the basis of any characteristic of the fibre web. In mechanical detection, the position detector 4; 4a is moved in the direction of the arrow with a full head, the thickness s of the fibre web layer increasing as the position sensor sends the control system data about the position of the outer surface of the fibre web. In figure 4, the position sensor 4; 4a is placed on the side of the reel core, on top of the fibre web, and it is moved in the direction of the arrow with a full head as the thickness of the fibre web layer increases. However, the position sensor could as well be located at the end of the rear roll, and then the thickness of the fibre web layer would be measured by means of say, a photoelectric sensor. In some cases, the sensor may also measure a physical property of the fibre web, such as light transmission, for instance, which allows calculation of the thickness s of the fibre web layer on the reel core in the control system 3. The arrangement also includes a force sensor 4; 4b for measuring the force F exerted by the reel core 21 on the reel cylinder 22. The force sensor operates only when the roll nip N is closed. The force sensor can also be replaced with a pressure sensor, which measures directly the nip pressure prevailing in the roll nip N between the reel cylinder and the reel core.

The analogue signals 41; 41a, 41b measuring the position and force are transferred from the force sensor 4; 4b and position sensor 4; 4a to the control system 3, where they are processed under the control function G(s) of the control system in order to control the pressure in the roll nip and the position of the reel core 21 and the reel cylinder 22 by means of the control signals 31 to be transmitted to the digital pack 7. The control signals 31 sent from the control system 3 are already in a digital form, so that they need not be converted into analogue form, unlike control signals sent to analogue valves. With the roll nip N closed, the pressure prevailing in the roll nip is adjusted on the basis of measurement results 41; 41b sent by the force sensor 4; 4b by opening and closing appropriate valves in the digital pack by means

of control signals 31. When the thickness s of the fibre web W around the reel core has increased to such an extent that the reel core 21 needs to be displaced relative to the reel cylinder 22, appropriate on/off valves V; V1.V5 in the control pack 7 are opened so that the volume flow of the fluid entering the hydraulic cylinder 5 is sufficient for generating a given hydraulic fluid pressure in the compression cylinder, which, in turn, generates the desired movement of the lever arm 5; 52 (piston) connected to the reel core 21. By altering the magnitude of the volume flow, the velocity of movement of the reel core can be controlled in the direction of the arrow with a full head. Even though the control mode were rapidly switched from control of the pressure in the roll nip N to control of the mutual position of the reel core 21 and the reel cylinder and vice versa, there would be no notable control fluctuation, because changes in the volume flow are controlled by rapidly operating on/off valves. In the arrangement 1 in figure 4, the digital valve pack 7 has five on/off digital valves V; V1..V5, the control resolution of this particular digital valve pack comprising $2^5 = 32$ states, which is enough for most reelers. By increasing the number of valves contained in the digital pack, even high resolutions are rapidly achieved; e.g. 16 on/off valves already achieves a control resolution of $2^{16} = 65536$ different states.

The control arrangement shown in figure 4 can also be connected with attenuation of vibrations generated in the roll nip. The amplitude and the frequency of the vibrations are measured with acceleration or force sensors, on the shaft of either of the rolls (21 or 22), for instance. The vibration signals are transferred to the control system 3, which controls the valves of the digital valve pack 7 under its control function G(s) to be switched open and off, so that the reel core 21 is made to vibrate in a phase opposite to an artificially detected vibration. The attenuation of the vibration is illustrated more in detail above in connection with figure 3.

Figures 5A and 5B illustrate the implementation of the arrangement of the invention at a coating station and the conversion of measurement signals from the sensors into control signals.

In figure 5A, the fibre web W passes through the roll nip N between the roll pair 2 formed of the roll 21 and the backing roll 22, the coating agent being transferred onto the surface of the fibre web in the roll nip from the surface of the roll and its backing roll. The coating agent is transferred onto the surface s of the rolls 21, 22 from the coating agent application stations 6; 61, 62, whose structure and operation

are conventional *per se*. When it is desirable to open or close the roll nip N, the roll 21 is shifted relative to the backing roll 22 with a hydraulic cylinder 5 connected to a bearing housing of the roll 21 and simultaneously the force exerted by the roll on the backing roll is changed with the hydraulic cylinder while the roll nip N is closed. When the fluid pressure of the cylinder portion below the piston head moving in the cylinder is increased, the roll nip opens, or when the roll nip is closed, the nip pressure decreases, whereas, as the fluid pressure of the cylinder portion above the piston head moving in the hydraulic cylinder is increased, the roll nip is closed, and with the roll nip closed, the nip pressure increases. The position of the roll 21 relative to the backing roll 22 is measured with position sensors (shown more in detail in figure 5B) located at the lower end of hydraulic cylinders at each end of the roll 21 and detecting the position of the piston moving in the cylinder. The force exerted by the roll on the roll 21 in the nip N, in turn, is measured on the basis of the compression force between the piston and the bearing housing, by means of a force sensor 4; 4b connected to the upper end of the piston. Figure 5A shows a force sensor 4; 4b functionally connected to a hydraulic cylinder 5 located at the first end of the roll pair, i.e. the end illustrated in the figure, a similar force sensor being provided at the other end of the roll pair 2.

Figure 5B illustrates the processing of measurement signals 4; 41 arriving from the force sensor 4; 4b used in the apparatus of figure 5A and the position sensor 4; 4a and the control of the switch means 7 on the basis of measurement signals. The force sensor 4; 4b measures continuously the force exerted by the roll 21 on the backing roll 22 in the roll nip N and indicates the force level as an analogue measurement signal 41; 41b by means of the voltage (U). The position sensor 4; 4a, in turn, measures continuously the position of the roll 21 relative to the backing roll 22 and indicates the position as an analogue measurement signal 41; 41a by means of the current level (A). The measurement signals are transferred to a controller 3, which converts the measurement signals 41; 41a, 41b into digital control signals 31 under its control function G(s). The control signals 31 are transmitted as such to digital valve packs 7; 7a, 7b, which increase and decrease liquid flows in portions of the cylinder 51 located on different sides of the piston head 52; 52a by means of on/off digital valves on the basis of control signals 31. Digital valves of the digital valve pack 7; 7a serve to adjust the pressure of the hydraulic fluid in the cylinder portion 51a on the left side of the piston head 52a of the cylinder 51 and digital valves of the digital pack 7; 7b serve to adjust the fluid pressure of the cylinder portion 51b on the right hand of the piston head 52a.

The system may comprise a switch between the control system 3 and the digital valve packs 7, for selecting the control mode between position control and force control, however, no such switch is usually needed, unlike a conventional control arrangement using both control valves and analogue connections, because the on/off valves contained in the digital valve pack have sufficiently rapid operation for switching the control mode from position control to force control and inversely, almost without any delay. The control arrangement of the invention has the additional marked advantage over an arrangement for controlling the roll position and the roll nip pressure using analogue control valves that control signals 31 from the controller 3 need not be converted into analogue control signals, yielding simpler control of the arrangement and reduced loss of information during signal conversions.

Figure 6A, again, is a simplified view of a "multi-zone roll" 23 equipped with pressurising means 5; 51 within the frame, and figure 6B shows the use of such a "multi-zone roll" in a multinip calender 20. The multi-zone roll has a stationary static frame 11 and hydraulic cylinders 5, 51 connected to the frame, which can be pressurised in couples each time. A mantle 23a rotates about the frame 11. Journaling 8 is provided between the mantle 23a and the frame 11. The pressurising of the hydraulic cylinders is controlled by the digital valve pack 7; 71, which receives control signals 31; 31a from the control system 3. Hydraulic cylinders 5; 52 provided at the ends of the multi-zone roll serve to control the calender pressure by the intermediation of the digital valve pack 7; 72. The digital valve pack 7; 72 controlling the calender pressure is also connected to the control system 3, from which it receives the control signals 31; 31b.

Different parts of the mantle can be pressurised in different ways by means of hydraulic cylinders 5; 51 supported by the static roll frame 11. The hydraulic cylinders 5; 51 are pressurised in couples each time, so that the illustrated multi-zone roll has five zones 51; 51a, 51b, 51c, 51d, 51e, each of which is pressurised with an individual fluid transfusion duct. Each of said fluid transfusion ducts is connected to one of the on/off valves of the digital valve pack 7; 71, which are controlled by means of control signals 31a from the control system 3. By opening and closing appropriate valves of the digital valve pack 7; 71 the desired zones 51 under the mantle 23a of the multi-zone roll can be pressurised. At the ends of the multi-zone roll 23 shown in figure 6A, hydraulic cylinders 5; 52; 52a, 52b are

provided, by means of which the multi-zone roll 23 can be raised and lowered. These hydraulic cylinders are controlled with a separate digital valve pack 7; 72, which receives control signals 31; 31b from the control system 3. The number of digital valves in the digital valve pack 7; 72 and the volume flow they transmit are selected so that the desired pressure levels of the hydraulic fluid are generated in the hydraulic cylinders 5; 52a, 52b, as explained above in connection with figure 1.

The operation of the hydraulic cylinders 5; 45 at the ends of the multi-zone rolls of the type shown in figure 6A and that of the pressurising means 5; 51 within the multi-zone rolls is controlled in conventional control arrangements by means of analogue control valves and switches. Such control arrangements are often susceptible to fluctuating control, because there are delays due to the operation of the control valves during the changes in the pressurisation of different zones 51a..51e. By contrast, in the control arrangement of the invention shown in figure 6A, the liquid flow from the hydraulic station (not shown in the figure) to the pressurising means 51 is controlled with the digital valve pack 7; 71, which has 5 on/off valves. Each valve opens and closes a fluid transfusion duct leading to a given hydraulic cylinder pair 51; 51a..51e under the roll mantle. The digital valves have rapid operation, so that the pressurisation in the different roll zones can be quite rapidly changed, allowing crown variation control requirements caused by the weight of the roll to be rapidly met. The other digital valve pack 7; 72, in turn, serves to change the nip pressure of the roll nips and also to open and close roll nips by varying the fluid pressure of hydraulic cylinders 5; 52; 52a, 52b at the ends of the roll. The roll nips can also be opened/closed at the desired rate by opening/closing appropriate valves of the digital pack, as explained above in conjunction with figure 2. A conventional prior art control system for controlling the functions of a multinip calender comprises a microcomputer, which receives continuously information about the nip parameters from measurement sensors measuring these parameters and which transmits, on the basis of these data, control signals to hydraulic cylinders controlling the crown variation within the rolls and pressurising the mantle and to hydraulic cylinders adjusting the nip pressure by means of analogue valves and switches. Before the control signals are sent, they are converted from a digital form into an analogue form with a view to controlling analogue control valves. By contrast, in the control arrangement of the invention, control signals 31 in digital form coming from the control system 3 need not to be converted into analogue form, because the control valve(s) have been replaced with digital valve packs, whose control signals are digital.

Multi-zone rolls are often used as the uppermost or lowermost rolls and also as idle rolls in multinip calenders. Figure 6B illustrates an exemplified vertically directed multinip calender 20, in which multi-zone rolls of the kind shown in figure 6A have been used as the uppermost roll 23; 23a and the lowermost roll 23; 23b in the set of rolls. The multi-zone rolls 23; 23a and 23b comprise pressurisation means within the rolls as shown in figure 6A and hydraulic cylinders 5; 52a, 52b have been connected to these rolls to be used for generating the desired nip pressure distribution and nip pressure in the multinip calender 20. In addition, these hydraulic cylinders serve to open and close calendering nips N in the set of rolls during a path interruption, for instance. There are no loading means within the rolls among the idle rolls 24; 24a, 24b, 24c between the uppermost roll 23; 23a and the lowermost roll 23; 23b, however, loading arms 12 have been connected to their bearing housings, and in turn, hydraulic cylinders 53; 53a, 53b, 53c have been connected to the loading arms for compensating the weight of the masses of the auxiliary means at the ends of these idle rolls, such as steam boxes and removal rolls (not shown in the figure). In addition to multinip calenders such as supercalenders, multi-zone calenders are generally used in presses for dewatering the fibre web.

The multinip calender 20 shown in figure 6B uses the control arrangement 1 of the invention for controlling the nip loads and nip load profiles of the roll nips N of a set of rolls. The control system 3 receives continuously information about the nip parameters from measurement sensors (not illustrated) measuring these parameters and controls the hydraulic cylinders 53; 53a, 53b, 53c compensating the weight of the auxiliary means on the basis of these data by sending control signals 31; 31d to the digital valve packs 7; 71. The number of on/off valves of the digital valve packs and the flow rate ratios have been selected such that the digital valve packs 7; 71a, 71b, 71c allow optimal compensation of the loads caused by the weight of the auxiliary means of the rolls 24; 24a, 24b, 24c. Each of the digital valve packs 71; 71a, 71b, 71c shown in figure 6B has five on/off valves, so that each of them is able to control $2^5 = 32$ different load compensating states. The control system 3 also controls the calendering pressure of the set of rolls and hydraulic cylinders 5; 52a, 52b functionally connected to the uppermost and the lowermost roll and controlling the opening and the closing of the roll nips by sending control signals 31; 31c to the digital valve pack 7; 72. The digital valve packs 7; 72; 72a, 72b controlling the calendering pressure and the opening and closing of the nips may be identical or

different. Each of the digital valve packs 72 shown in figure 6B has five on/off valves, so that they can achieve $2^5 = 32$ different control states of calender loading and for the rate of opening/closing the roll nips N.

Figures 7A and 7B illustrate the control arrangement and method of the invention as a block diagram.

Figure 7A is a block diagram of the control arrangement 1 of the invention for controlling the position and/or force of two elongated rolling devices in the roll nip N between two elongated rolling device pairs 2 in a paper machine. The rolling devices comprise a roll and its backing roll or a roll and a doctor blade, for instance. The control arrangement 1 comprises, as shown in figure 7A, a measuring means 4 for measuring the position and/or force of the rolling device or any variable acting on these and for sending a measurement signal 41 to the control system 3. The control arrangement 1 further comprises a hydraulic means 5, by means of which the position and/or force of the rolling device is changed in the roll nip, a switch means 7 for controlling the volume flow of the hydraulic means and a control system 3 for receiving a measurement signal 41 and for comparing the information contained in the measurement signal with the set value of the variable in order to generate a control signal 31 and to transmit it to the switch means 7. The switch means has receive means for receiving and processing a control signal and at least one digital valve pack having on/off valves, which can be opened and closed on the basis of a control signal in order to change the fluid pressure of the hydraulic means and/or the liquid flow rate to the hydraulic means.

In accordance with figure 7B the control method, in turn, serves to control the position and/or force of an elongated rolling device in the roll nip N between the rolling device pair 2 formed of two elongated rolling devices in paper machines. The position of the rolling device relative to the other rolling device and/or the force exerted by the rolling device on the other rolling device or any variable acting on these is measured. The measured variable value is compared with the set value of said variable in order to obtain the difference value of the variable. The difference value is used as a basis for adjusting the position of the rolling device and/or the force it exerts on the other rolling device with the aid of the hydraulic means. The fluid pressure of the hydraulic means and/or the liquid flow rate to the hydraulic means is changed in order to alter the difference value by opening and/or closing at least one on/off valve in the digital valve pack connected to the hydraulic means.

Only a number of embodiments of the method of the invention and of the related control arrangement has been described above, and it is obvious to those skilled in the art that the invention can be implemented also in other ways within the scope of the inventive idea defined in the claims.

Consequently, arrangements utilising a digital valve pack can be applied for partly or completely compensating loads caused by nip pressures of vertically positioned multinip calendars, opening and closing velocities of the roll nip and auxiliary equipment of the idle means, which are of the type disclosed by DE patent specification 10101182.

With the use of the arrangement of the invention, the mass of rolls can also be controlled in an arrangement of the kind disclosed by DE patent application 10006299, in which the valve 32 shown in figure 2 of the patent application is replaced with a digital valve pack, which closes and opens rapidly flows from pumps 23 and 25, allowing the velocity of movement of the piston moving within the roll and the fluid amounts within the roll to be rapidly changed.

In the embodiment illustrated in figures 5A to 5B above, the nip pressure of the roll nip and the opening and closing of the roll nip are adjusted in the apparatus used for fibre web coating by means of the control arrangement of the invention. The coating agent is transferred onto the fibre web in the roll nip between the roll and its backing roll from the surface of the roll and/or the backing roll or from endless belts rotating about the roll and/or its backing roll. The coating agent is transferred onto endless belts of the roll and/or its backing roll or rotating about the roll and/or its backing roll at application stations, which in several embodiments include an application means (= rolling device) pressed against the roll or the endless belt rotating about the roll, such as a blade or a rod. The load pressure between the application means and the roll or the endless roll rotating about the roll can be changed with a hydraulic actuator connected to the application means, such a hydraulic cylinder, in order to control the thickness and smoothness of the coating agent. The arrangement of the invention allows rapid and precise action on the load pressure between the application means and the roll or the endless belt rotating about the roll by conducting the hydraulic fluid flow passing to the hydraulic actuator through the digital valve pack, which has an appropriate number of on/off valves for achieving the desired load pressure level.

The load pressure between the doctor blade (= rolling device) and the roll surface can also be altered with the arrangement of the invention in doctor blades wiping the roll surface, which are commonly used in apparatuses for calendaring a fibre web, among other things, by conducting the hydraulic fluid flow pressing the doctor blade against the roll through the digital valve pack, which has an appropriate number of on/off valves for achieving the desired load pressure level.

The examples above describe the use of digital valves having two states. Digital valves may also have several states. Thus, a digital valve having say, three states could transmit oil into two directions, and in one position, it would not allow fluid to permeate at all. The operation of the valve can then be depicted as follows:

State + 1: the valve transmits oil into a first direction, to the front side of the piston in the cylinder, for instance.

State 0: the valve is closed and does not transmit fluid.

State –1: the valve transmits oil into a second direction, e.g. to the rear side of the piston in the cylinder, i.e. to the side of the piston rod.

Such a valve would operate in the way of an analogue servo valve (the valve being closed in the centre of the spindle), but would open to 100% or by digital steps each time. This allows the same valve to drive the nip into closed position with a full flow or to drive it into open position with a full flow, the opening/closing velocity of the roll nip depending on the size of the valves/valve combinations of the digital pack used in each case. The three-step valve digital valve mentioned above (having three states) is also preferably used in the vibration control of the roll nip, and then the digital valve can transmit oil into two directions.

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